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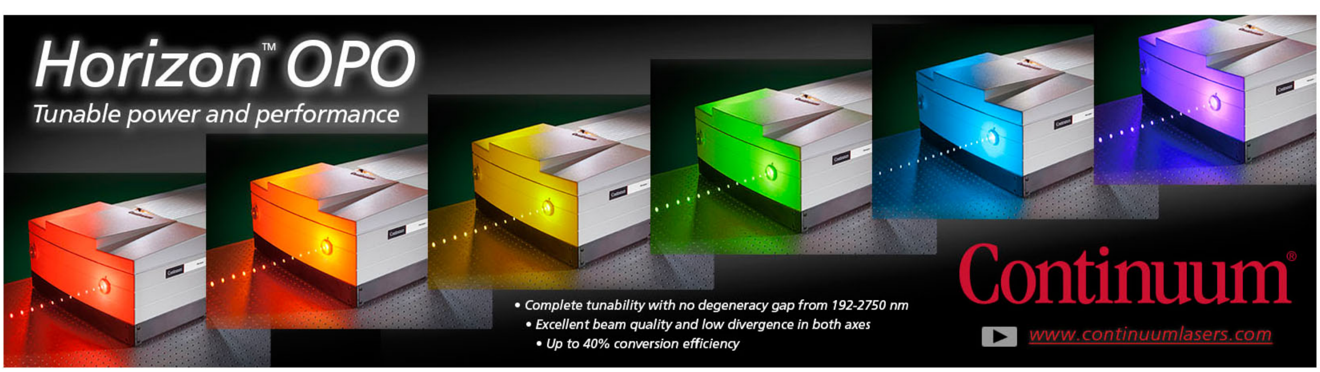

Optical switching of nematic liquid crystal by means of photoresponsive polyimides as an alignment layer

Gi Heon Kim, Shintaro Enomoto, Akihiko Kanazawa, Takeshi Shiono, and Tomiki Ikeda[a)]
Research Laboratory of Resources Utilization, Tokyo Institute of Technology, 4259 Nagatsuta, Midori-ku, Yokohama 226-8503, Japan

Lee-Soon Park
Department of Polymer Science, Kyungpook National University, 1370 Sankyuk Dong, Taegu 702-701, Korea

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Photosensitive polyimides (PIs) as an alignment layer induced optical switching of nematic liquid crystal (NLC) on photoirradiation at 366 nm. The orientation of NLC molecule was changed from homogeneous to homeotropic alignment on photoirradiation with a dc electric field as a bias. The optical switching behavior of NLC was largely affected by the chemical structures of PIs. © *1999 American Institute of Physics.* [S0003-6951(99)02748-5]

Much attention has been paid to photonics as the most promising technology for information processing in the next generation.[1–5] In photonics, light is controlled by another light, and to control the properties of light, it is most effective to use materials which can change their refractive index upon photoirradiation. Liquid crystals (LCs) show a large optical anisotropy, and a large change in refractive index can be obtained by changing their alignment, which is obviously advantageous for photonic applications.[6,7] At the present, change in the alignment of LCs is brought about by an external electric field applied across the LC cell. If the properties of the alignment layer can be changed by light, a change in the alignment of LCs could be induced by light, which results in a change in the refractive index of the system by light.

Among various polymer materials, polyimides (PIs) (see Fig. 1) are generally used as the alignment layer for obtaining homogeneous alignment of nematic LCs (NLCs) because of their simplicity and reliability in handling.[8–11] In this study, we provided PI alignment layers with photosensitivity to manipulate the alignment of NLCs by light as a stimulus and explored the change in alignment of the NLC on photoirradiation with a dc electric field as a bias. The precursor poly(amic acid) of the PI was deposited first onto glass substrates coated with ITO by spin coating of 3% precursor solution and the film was subsequently heated at 100 °C for 1 h to evaporate the solvent and imidized at 250 °C for 2 h. The PI film was rubbed to obtain homogeneous alignment of the NLC. The LC cell was assembled using pairs of substrates thus prepared with their rubbing directions antiparallel. The gap of the LC cell was controlled by using a 5-μm-thick Mylar spacer. 4′-Penty-4-cyanobiphenyl (5CB) was introduced into the cell in the isotropic phase by capillary action.

Figure 2 shows the measurement system for optical switching behavior of the cell. The NLC cell was placed between two crossed polarizers and temperature controlled, and the bias voltage (dc) was applied across the cell. The intensity of the transmitted He–Ne laser beam at 633 nm was measured with a photodiode and then fed into a computer. Photoirradiation was performed with a high-pressure mercury (Hg) lamp at 366 nm.

We explored the change in the alignment of 5CB with the photosensitive PIs as an alignment layer by light with a dc electric field as a bias. Figure 3 shows the transmittance–

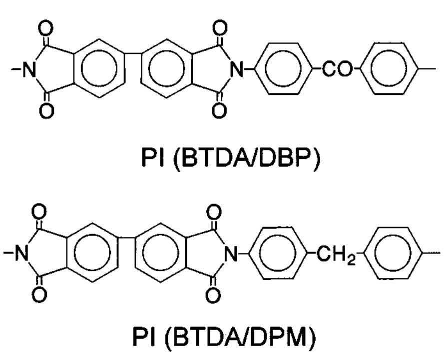

FIG. 1. Chemical structures of PI(BTDA/DBP) and PI(BTDA/DPM) used in this study.

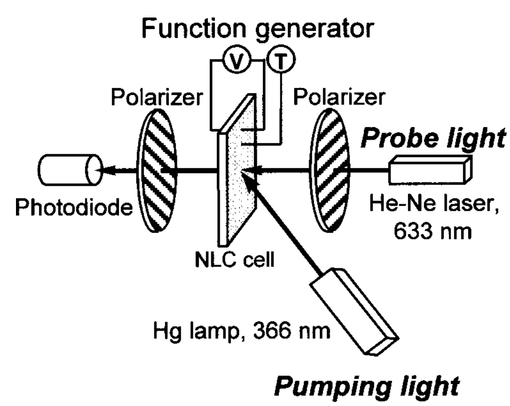

FIG. 2. Schematic diagram for the electro-optical response measurement of NLC (5CB) with the photosensitive PIs as the alignment layer.

[a)]Author to whom correspondence should be addressed. Electronic mail: tikeda@res.titech.ac.jp; URL: http://www.res.titech.ac.jp/polymer.

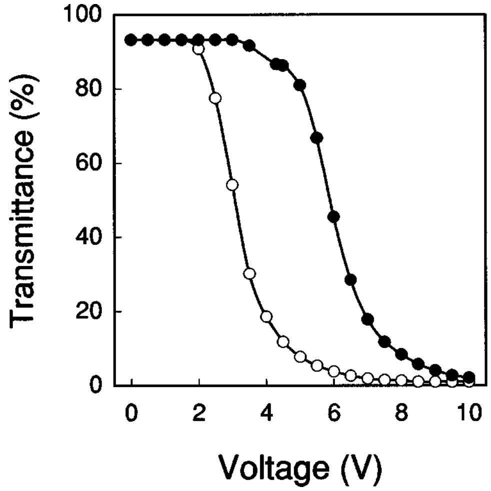

FIG. 3. The electro-optical response of 5CB with PI(BTDA/DBP) as the alignment layer at 30 °C. The pretilt angle of the cell was 4.7°. ●, before photoirradiation; ○, during photoirradiation at 0.6 mW/cm^2.

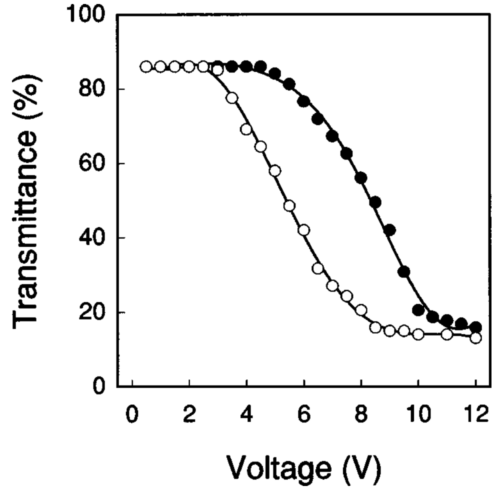

FIG. 5. Electro-optical response of 5CB with PI(BTDA/DPM) as the alignment layer at 30 °C. The pretilt angle of the cell was 4.3°. ●, before photoirradiation; ○, during photoirradiation at 0.6 mW/cm^2.

voltage ($T-V$) profile of 5CB with PI(BTDA/DBP) as an alignment layer. It was observed that with increasing dc applied voltage, the transmittance remained unchanged until ~4 V and then decreased steeply. This is well known as an electro-optic effect of NLC, which results from the change in alignment of the NLC from a homogeneous state to homeotropic alignment, and its behavior is affected by the alignment layer thickness and cell cap. A threshold voltage for the change in the alignment of 5CB in this case was about 6 V. We also measured the $T-V$ profile under photoirradiation at 366 nm (light intensity, 0.6 mW/cm^2). Very interestingly, the $T-V$ profile under photoirradiation shifted to low voltage and the threshold voltage decreased to 3 V, as shown in Fig. 3. The largest difference in the $T-V$ profile before and during irradiation occurred at 4.5 V. So, we irradiated the cell at 366 nm while 4.5 V (dc) was applied across the cell as a bias voltage. As shown in Fig. 4, the transmittance of the He–Ne laser beam at 633 nm decreased on photoirradiation and recovered to the initial value when photoirradiation was ceased. This behavior is due to the change in alignment of 5CB from the homogeneous state to the homeotropic state. This optical switching could be repeated by the on and off of the excitation light at 366 nm. These results indicate that the alignment of 5CB can be reversibly changed by light with PI(BTDA/DBP) having a photosensitive moiety as an alignment layer.

We next explored the optical switching of 5CB with PI(BTDA/DPM) as an alignment layer with the dc electric field as a bias. We measured the $T-V$ profile of the cell before and during irradiation as previously stated. As shown in Fig. 5, the $T-V$ profile during irradiation shifted to low voltage and the threshold voltage decreased to 5 V. However, in this case the slope of the $T-V$ profile was not as steep as that shown in Fig. 3 and the threshold voltage for the change in the alignment was higher than that of PI(BTDA/DBP) having benzophenone moiety. We applied 7 V (dc) as a bias voltage and examined the optical switching behavior of the NLC cell, and the results are shown in Fig. 6. The transmittance could also be reversibly changed by the on and off of the excitation light at 366 nm. The change in the transmittance, however, was smaller than that of the NLC cell with PI(BTDA/DBP).

In this study, we found that the photosensitive PI alignment layers induced the optical switching of 5CB. By the

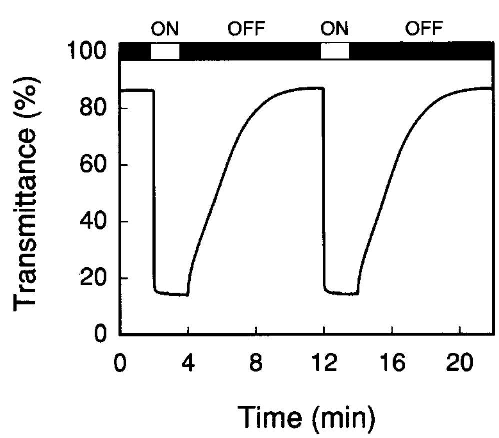

FIG. 4. Optical switching of 5CB with PI(BTDA/DBP) as the alignment layer. The switching behavior was examined at 30 °C and photoirradiation was performed at 366 nm (light intensity, 0.6 mW/cm^2) with the dc bias voltage of 4.5 V.

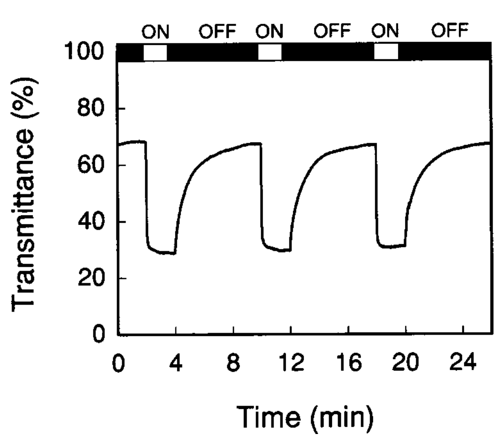

FIG. 6. Optical switching of 5CB with PI(BTDA/DPM) as the alignment layer. The switching behavior was examined at 30 °C and photoirradiation was performed at 366 nm (light intensity, 0.6 mW/cm^2) with the dc bias voltage of 7 V.

surface analysis, no appreciable photochemical reaction of PI was observed on the surface by light; the optical switching might be due mainly to photophysical changes of the PI surface.[12–15] However, further works are necessary to understand fully this phenomenon. The optical switching of the NLC cell with photosensitive PIs as alignment layers is a driving method of NLC, which is applicable to optical switching devices of NLCs.

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